Mars Network Science Mission (MNSM)
An ESA mission study

A. Chicarro (Study Scientist, ESA/ESTEC)
and the MNSM Science Definition Team

MNSM Study Team

Science Experts

- Bruce Banerdt – NASA/JPL, Pasadena ➔ seismology
- Doris Breuer – DLR, Berlin ➔ interior geophysics
- Veronique Dehant – ROB, Brussels ➔ geodesy
- Luciano Iess – Univ. Sapienza, Rome ➔ geodesy
- Philippe Lognonné – Univ. P-M Curie, Paris ➔ seismology
- Angelo Rossi – Univ. Bremen ➔ geology
- Aymeric Spiega – LMD, Paris ➔ atmospheric physics
- Colin Wilson – Oxford Univ. ➔ atmospheric physics

ESA

- Agustin Chicarro – ESA/ESTEC ➔ study scientist
- Kelly Geelen – ESA/ESTEC ➔ study manager

Previous Study Teams

- Marsnet (92), InterMarsnet (96), Netlander (99) and Mars-NEXT (09)

Programmatic Framework

Mars Robotic Exploration Programme (MREP) – part of the ESA/NASA Joint Mars Exploration Programme (JMEP)

- Aim: return samples from Mars in the 2020s
- Initially spanned several launch opportunities including rovers and orbiters
  - ☞ 2016 Trace Gas Orbiter (TGO) + ESA Entry, Descent, and Landing Demonstrator Module
  - ☞ 2018 ExoMars AND MAX-C rovers merged into single rover mission
- Currently being reassessed due to budgetary situation
- To be prepared for 2020-22: ESA initiated further mission studies
  - ☞ Martian Moon Sample Return (MMSR)
  - ☞ Mars Network Science Mission (MNSM)

  And previously studied:
  - ☞ Atmospheric sample return
  - ☞ High-precision landing

Goal of current study

- Bring the candidate missions to a level of definition enabling their programmatic evaluation, including development schedule and Cost at Completion to ESA.

Tasks of Study Team

The Science Study Team was asked to

- (a) Describe the science case for such a mission
- (b) Propose a baseline mission scenario or concept
- (c) Propose the baseline science instrumentation

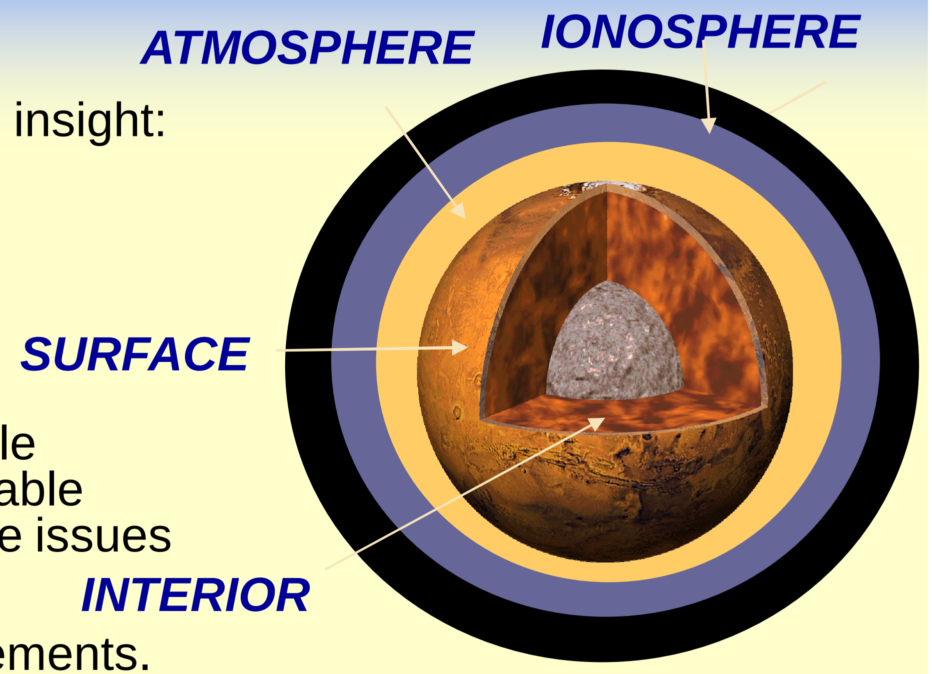
Constraints:

- Launch with Soyuz
- 'ESA affordable' (but can have collaboration), Cost at Completion <~750 – 800 MEuro
- Extensive reuse of existing studies

MNSM Timetable

MNSM: 2011/2012 timetable and key events	
Event	**Date**
Setting of Science Study Teams for supporting the Mission definition for the Mars network science mission & Mars moon sample return	April 2011
SSTs reports on Mars Network and Martian Moon Sample Return missions	July 2011
Completion of ESA internal studies (CDF) for the mission definition	November 2011
Completion of industrial studies on MSR Orbiter and Mars Precision Lander missions	December 2011
Programmatic consolidation	December 2011-January 2012
Presentation to PB-HME	February 2012
Elaboration of international collaboration schemes	January –June 2012
PB-HME decision on way forward for C-Min(2012)	June 2012

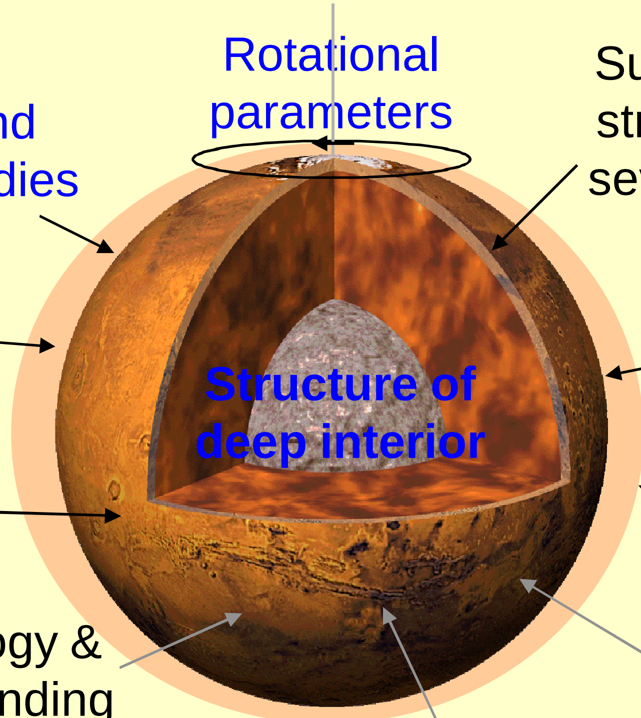
Network Concepts

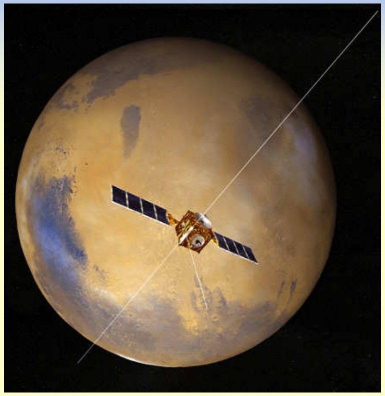


- Combined investigations provides unique insight:
    - Planetary Formation & Interior
    - Atmospheric & Climate Processes
    - Geological Features & Evolution
    - Habitability & Risks for Future Missions
- Simultaneous measurements from multiple locations (Network of science probes) enable unique opportunity to address key science issues (e.g. seismology, geodesy, meteorology).
- Coordinating surface and orbital measurements.
- Network Science is of very high priority to the science community in Europe and worldwide.
- The Network concept has a long heritage, including ESA (Marsnet, Intermarsnet), NASA (MESUR) and FMI (MetNet) studies, and even reaching Phase-B with the CNES Netlander mission.
- Significant development history of many instruments from NetLander & Beagle-2 reduces risk for MNSM implementation.

Scientific Goals

A Mars Network Science Mission offers the potential to address a broad range of scientific objectives:





Addressing these ‘global’ science objectives will complement the exobiological objectives of ExoMars, and provide a better understanding of Mars’ evolution.

This is key to placing the following step in the scientific exploration of Mars, i.e. Mars Sample Return, into context.

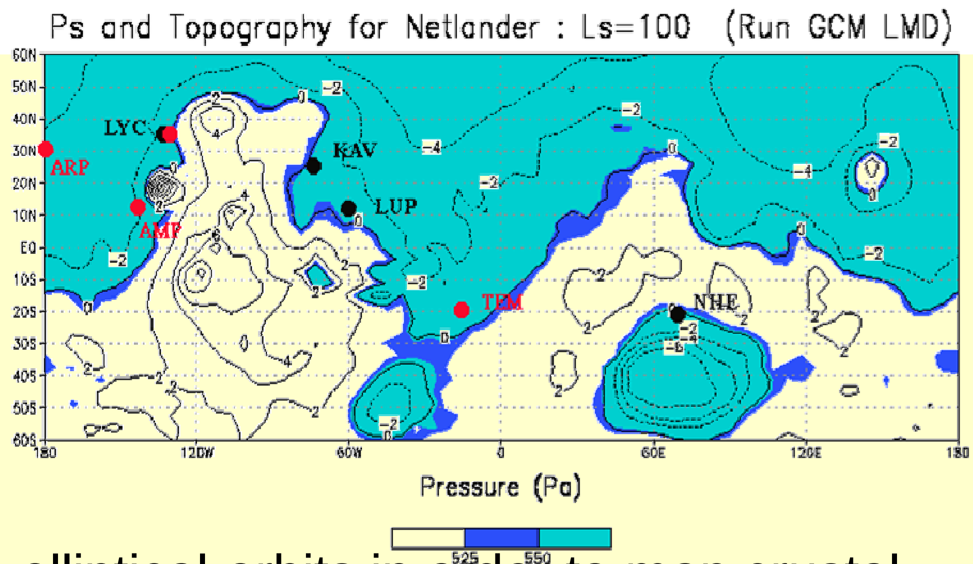
Number of Landers

For seismology and meteorology, the scientific return clearly depends on the number of landers:

1) → basic seismicity level
2) → quake vertical projection
3) ***<u>→ 3D quake depth</u>***
4) → provides redundancy within the Network and access to the inner core

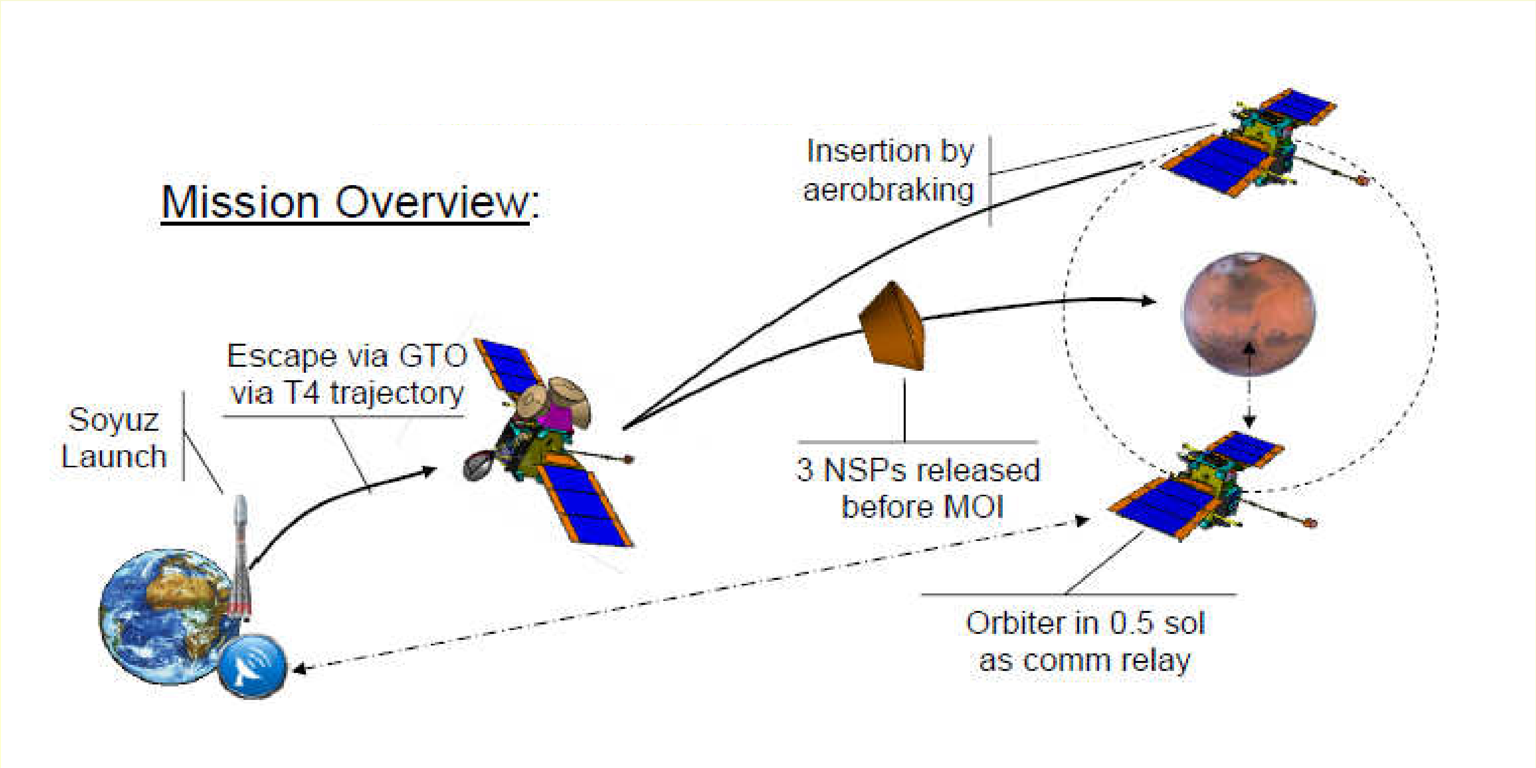
Phase A will assess deployment of **3 probes** → preliminary outcome on mass availability may result in reconsideration of number of probes

- Examples of Network configurations:
  - Tharsis triangle + antipode
  - Tharsis triangle + Hellas basin



- Aerobraking allows <u>low-altitude elliptical orbits</u> in order to map crustal magnetic anomalies and monitor atmospheric escape and its interaction with the solar wind.

Mission Building Blocks



The mission main function is to land a number of surface static probes of 150-kg class on the Mars surface, complemented by an orbiter.

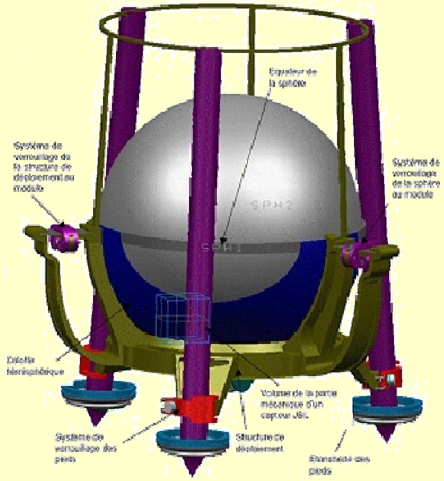
Could be done without orbiter = mission simplification
Mission considered with Soyuz or Ariane 5
Backup stand alone mission in case MSR is delayed

Network Science

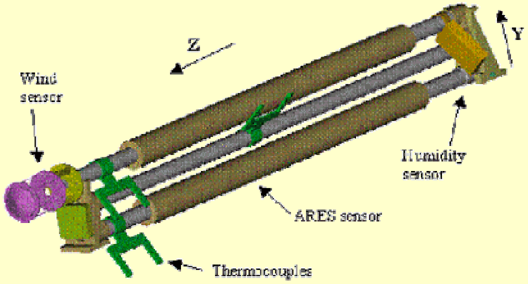
Simultaneous measurements - payload suite drawing on existing heritage.

- Seismology: interior structure, crustal thickness
- Geodesy: rotational parameters, CO_2 cycles
- Meteorology: climate, global atmospheric circulation

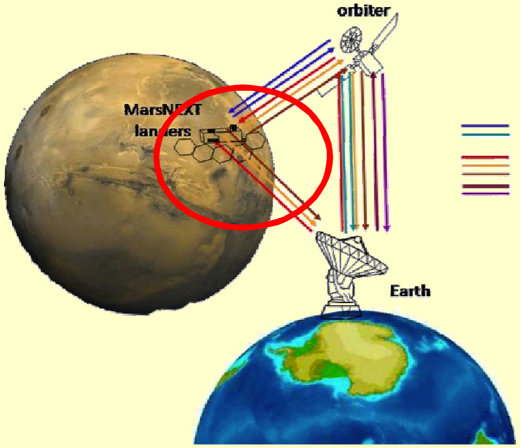
MAGNETOMETER



SEISMOMETER



METEOROLOGICAL BOOM



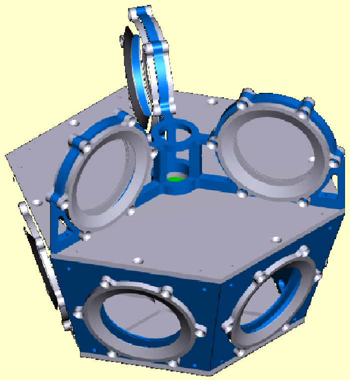
RADIO SCIENCE

Reference network payload = 8 kg (incl. margin)

Landing Site Science

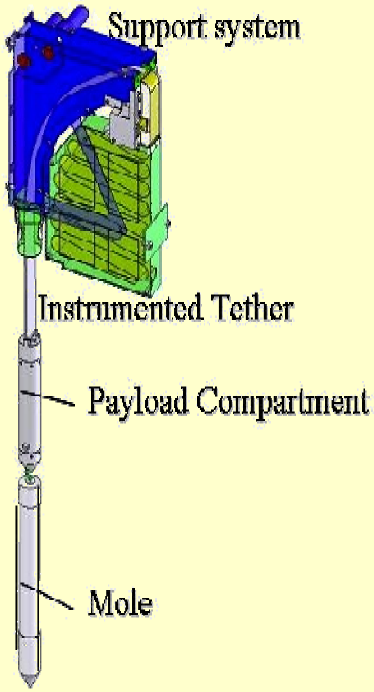
Science of opportunity – in-situ instrumentation draws on existing heritage

- Site Characterisation: geology, geochemistry
- Sub-surface: heat-flow, soil properties, magnetism
- Surface-Atmosphere interactions: H_2O

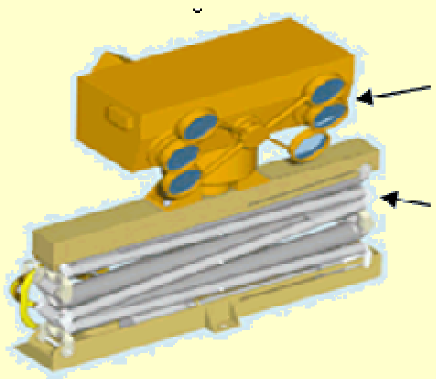


ALPHA- P SENSOR

Reference in-situ payload
= 4 kg (incl. margin)



INSTRUMENTED MOLE

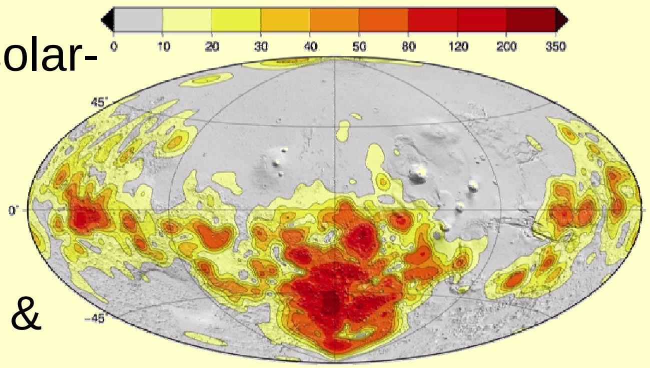


SITE IMAGING SYSTEM

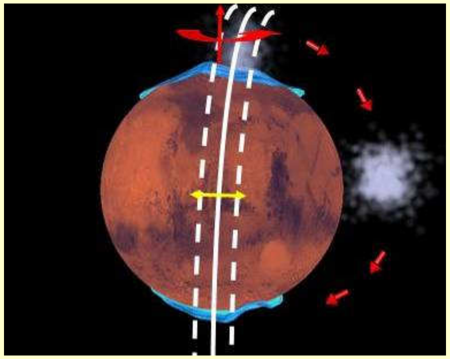
Orbital Science

Orbital Payload - maximise use of low altitude orbits, relay network science to Earth, complement atmospheric science from surface, radio science

- Geodesy: state, radius & composition of martian core
- Escape: atmospheric evolution, solar-wind interaction
- Magnetism: mapping crustal anomalies in detail
- Atmospheric chemistry: Profiles & interactions

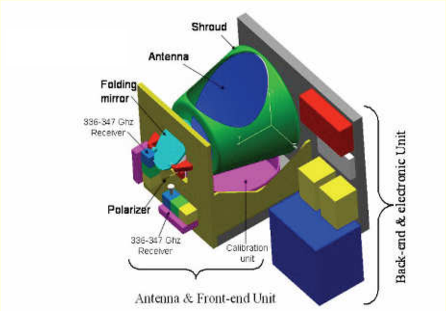


Magnetic Crustal Anomalies - MGS

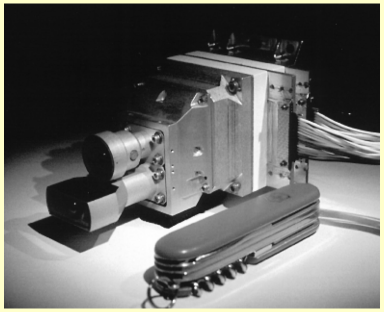


CO_2 EXCHANGE

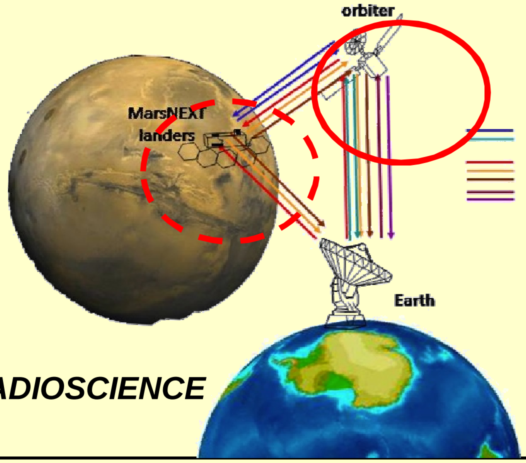
Reference orbital payload = 30 kg (incl. margin)



MICROWAVE SPECTROMETER

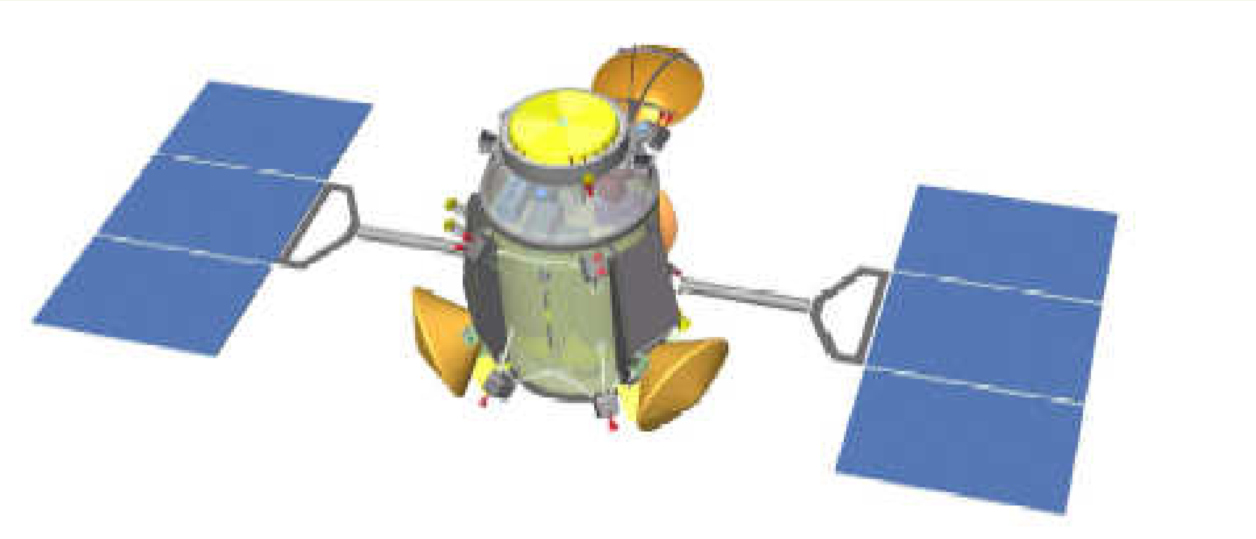


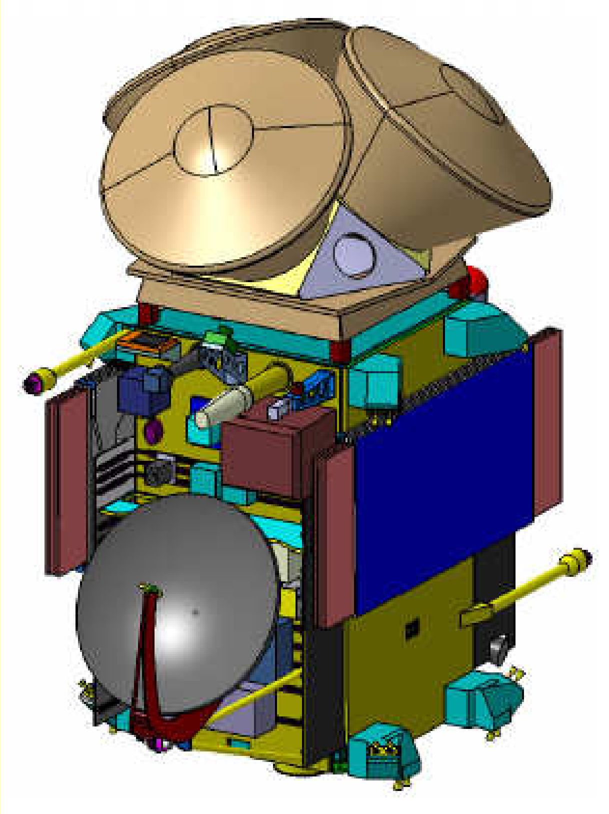
WIDE ANGLE CAMERA



RADIOSCIENCE

Orbiter-Carrier Design





- Orbiter configuration driven by 4 large propellant tanks
- Complex AOCS architecture to cope with main engine failure at MOI, aerobraking, probe separation, rendezvous (24X22 N thrusters)
- “Conventional” solar array (max T = 150-170 ℃)
- Heritage from Mars Premier, MEX, ExoMars

Entry, Descent & Landing

EDL strategy being looked at:

1. Entry
2. Descent: parachute activated at relevant Mach number
3. Front shield jettison
4. Lowering of the lander
5. Airbag inflation
6. Altitude-triggered retro-rockets
7. Bridle cut, back cover drifts away
8. Probe free-fall
9. Bouncing
10. Resting position, end of EDL sequence

    Airbag removal (deflation or separation). Probe deployment

Probe Design

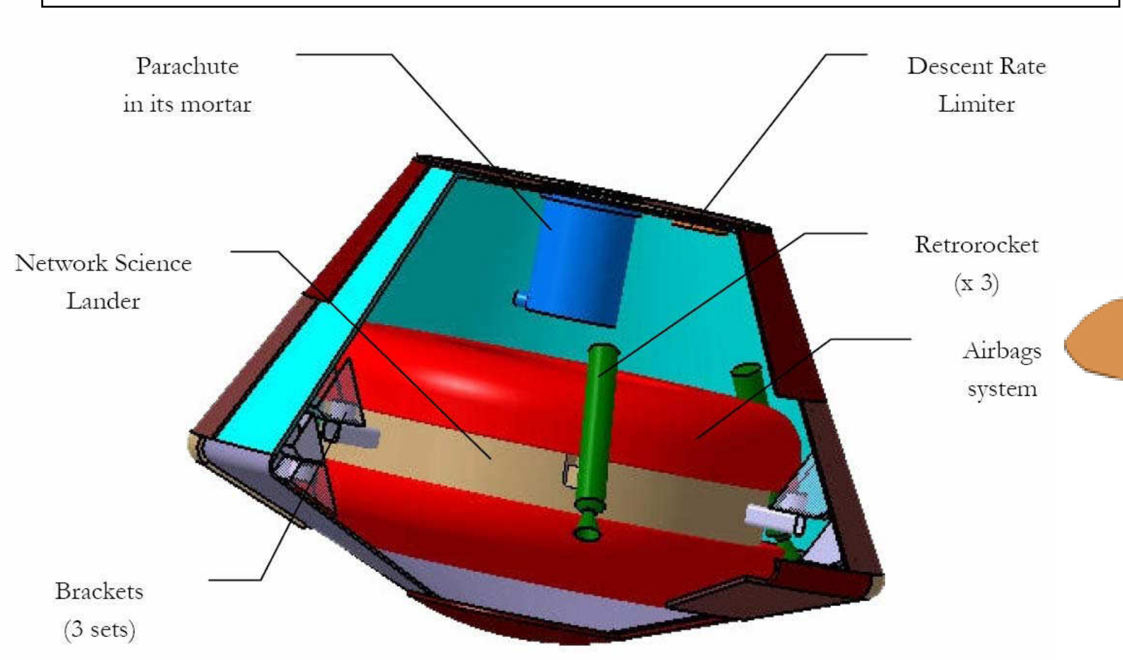
5.7 km/s entry velocity

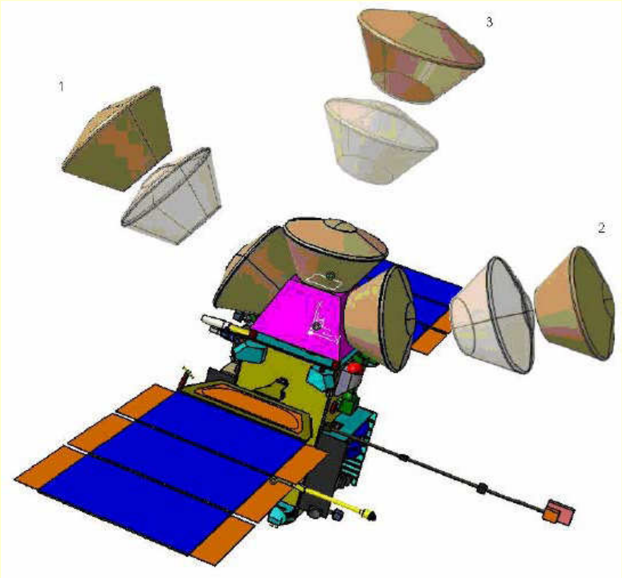
130 kg for Soyuz, 170 kg for A5

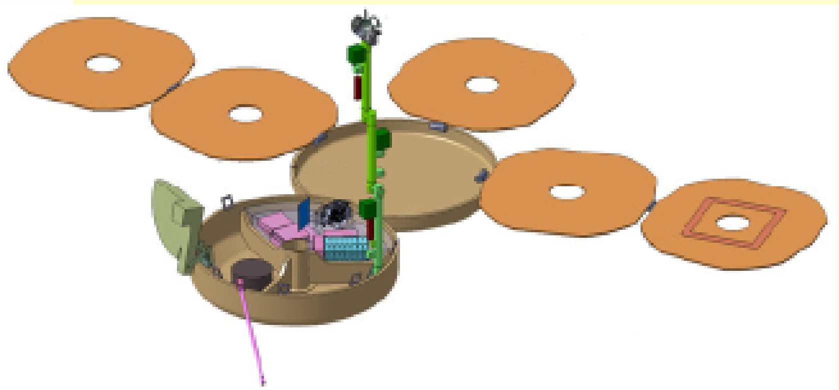
70º half-cone angle

Max. heat flux ~ 1 MW/m^2 at 0.006 bar

Norcoat Liege (Beagle 2, ExoMars)







Technology Development

Landing system
- Breadboarding of airbag for small landers

EDL communications
- Compact dual X-band/UHF Proximity-1 communication EM

Aerobraking demonstrator

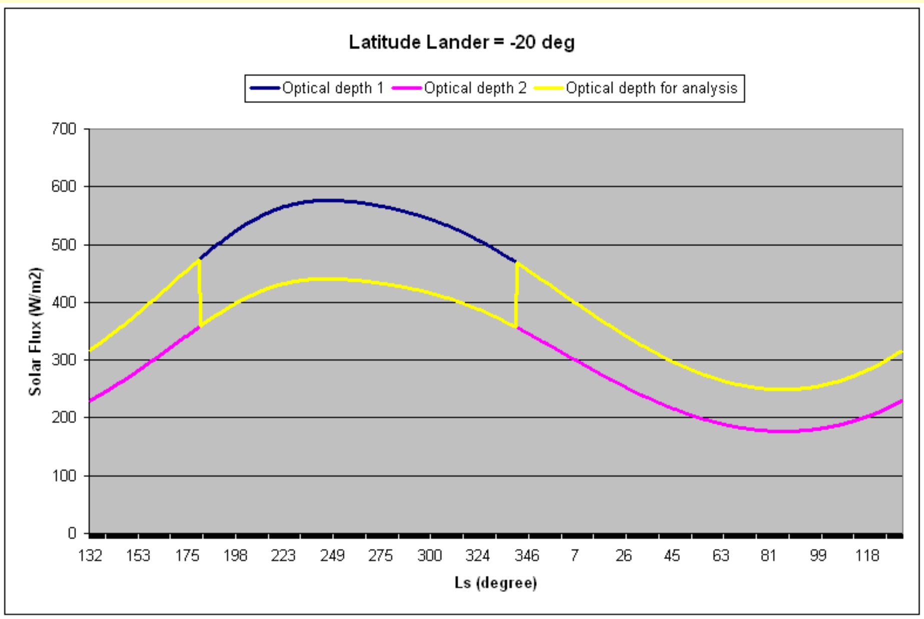
Planetary altimeter for EDL GNC

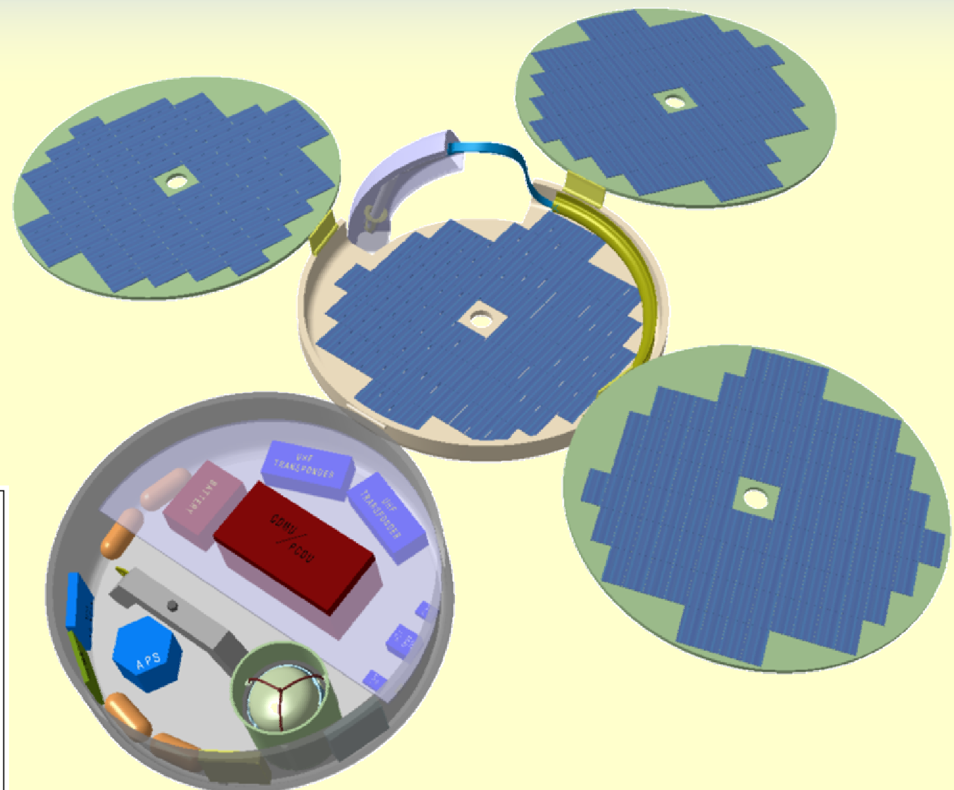
Subsonic parachute testing

EDL system optimization:
- 2 parachutes with bouncing airbags, no retro-rockets - 1 parachute, retro-rockets and airbags
- Need for lateral control versus more robust airbags

Surface Lander

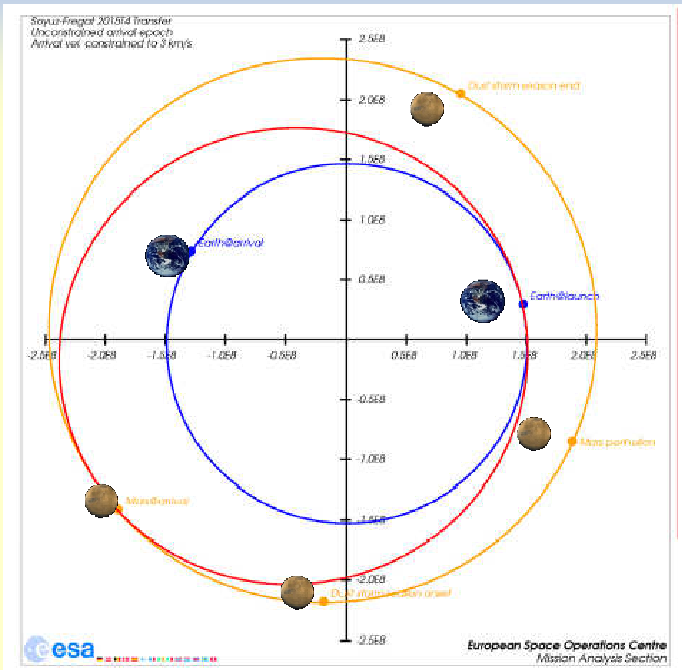
- Solar power-based with RHUs
- Landing latitude range: 15 S to 30 N to keep mass down (SA size)
- Configuration Beagle 2-like with self-righting mechanism
- Capability to hibernate during Global Dust Storm Season (τ=2)





- Payload accommodation the major driver
- Mild electronics integration proposed
- Customised Mole packaging required

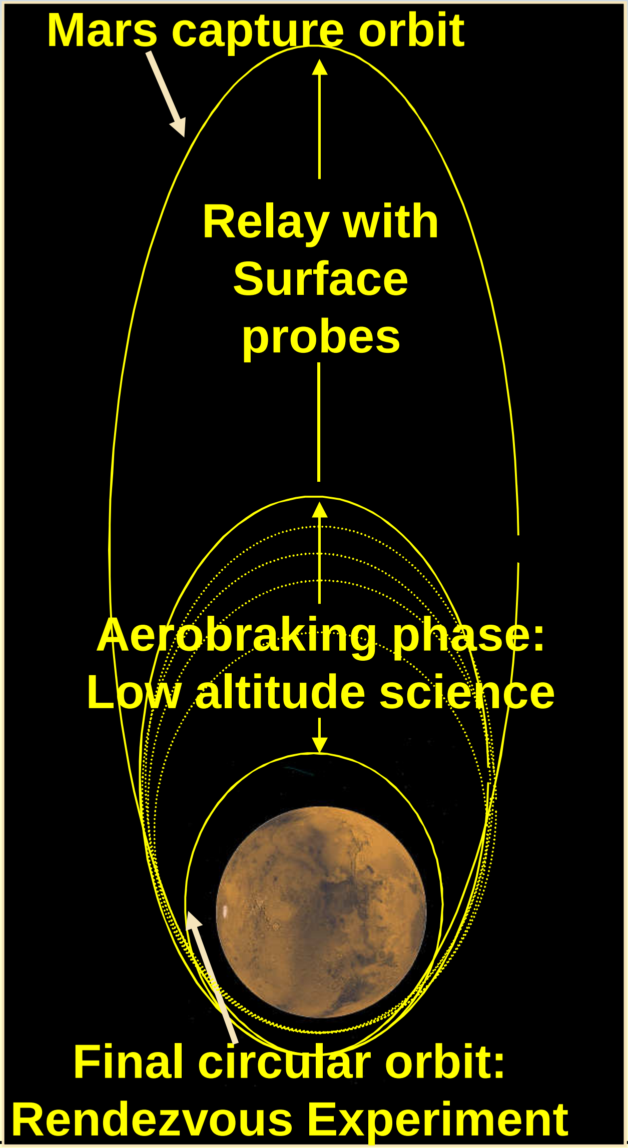
Launch & Transfer



- Launcher performance and launch window lead to a mass carried to Mars:
  - Total Network Science Probes mass of 350kg
  - Orbiter dry mass of about 700 kg (incl. payload)

- Launch date: case of 2016 window
- Launch: Soyuz 2.1b from Kourou to GTO
- Escape to Mars transfer from GTO by S/C propulsion
- Long Transfer (baseline type 4):
  - Arriving in February 2018 earlier than Global Dust Storm,
  - Arrival date consistent with feedback from technology demonstration required for MSR
- Backup transfer available with launch in early 2017, arrival in late 2018 (Type 2 + Earth Swing-By)
- Release of Network Science Probes from hyperbolic arrival trajectory

Mars Arrival



Sequence of operations in Mars orbit:

- From capture orbit combination of chemical manoeuvres and aerobraking (6 months max) to circularise orbit
- During aerobraking : low altitude orbital science
- Acquisition of Mars Final Orbit: circular 500X500 km ~45 deg identical to MSR baseline orbit for rendezvous representation
- Performance of rendezvous and capture experiment (~2 months)
- Second phase of orbital science and performance of radioscience with Surface Probes
- Availability as relay for MSR Lander
- Throughout all operations, relay with Surface Probes, initially with support from existing Mars Orbiters

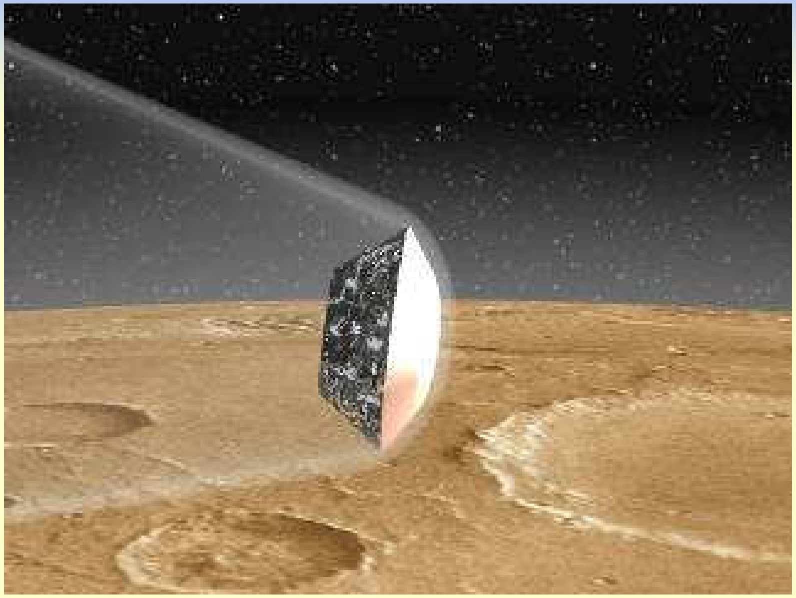
EDL & Surface Operations

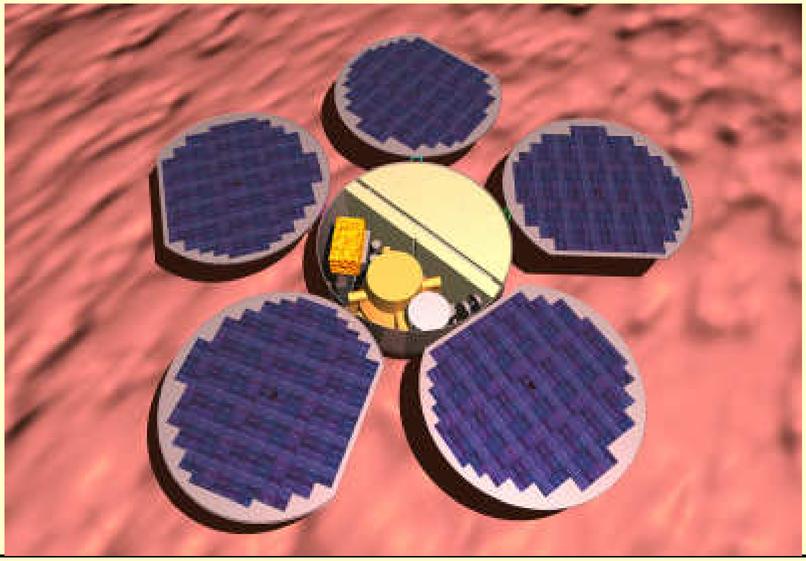
EDLS of Probes

- Ballistic entry,
- Descent based on parachute,
- Landing by bouncing airbags
- Capability of landing at MOLA<0

Surface Operations:

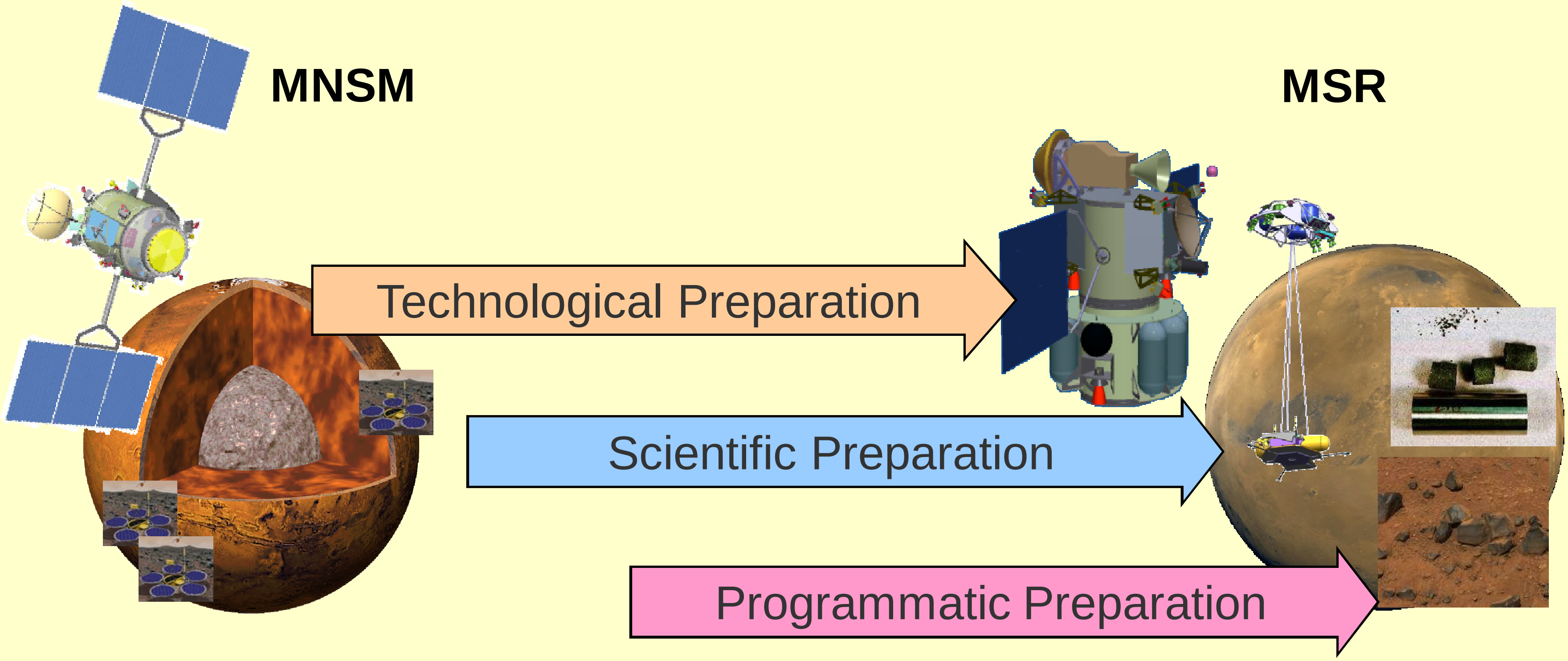
- Static platforms, solar power-based with RHUs
- Landing latitude range: 30 S to 30 N
- Nominal lifetime on the surface: 1 Mars year





Concluding Remarks 1

MNSM represents a fundamental milestone for Europe to prepare for Mars Sample Return



MNSM could provide pre-operational support to the MSR mission

Concluding Remarks 2

- Network Science is vital in order to achieve fundamental Mars scientific objectives, such as the study of Mars interior, its rotation and atmospheric dynamics, fully complementary to ongoing Mars missions and MSR.
- The MNSM represents a timely scientific opportunity to pursue Mars geophysical exploration, building on the heritage gained by Mars Express (radar sounding).
- The IMEWG has supported the Network concept since its foundation; in addition, very strong interest exists in the scientific community worldwide (and especially in USA, Japan, China, Russia & Canada).
- The Mars Habitability Workshop has shown the importance of geophysical data in providing an habitability framework and helping in the interpretation of future returned samples from Mars.

The Mars Network Science Mission is a very powerful and unique tool for Mars science, including habitability.